AIRWAYS OBSTRUCTION IN CHILDREN[1]

THELMA MORONY, M.A.P.A.

Honorary Consultant Thoracic Physiotherapist, Royal Alexandra Hospital for Children, Sydney. Winston Churchill Fellow, 1966.

Over the past decade physiotherapy has played an increasingly important role in the treatment of airways obstruction. Obviously, the same basic principles of treatment apply to both children and adults—however, I wish to emphasise differences which exist, because of differences in years, from the neo-nate to the adolescent.

I should like to discuss age as a factor in airways obstruction under the following headings: anatomical and physiological differences, conditions encountered, and physiotherapy.

ANATOMICAL AND PHYSIOLOGICAL DIFFERENCES

Airways Conductance and Resistance

At birth, there are 20 million alveoli present. By the age of eight, these grow in size and in number to the full adult number—300 million. (Dunnill, 1962.)

In the infant, and up to the age of about five, there are the same number of airways as in the adult, but these are relatively much smaller in size. In the adult, the total cross-section of all bronchioles is 180 cm^2 (that is, 70 times the area of the trachea), and the bulk of resistance to the air flow in and out of the lungs is in the main bronchi and the trachea (80% in the normal adult).

In the infant, however, the total cross-sectional area of the bronchioles, proportionately, does not exceed the area of the trachea by as much and, therefore, a significant amount of resistance is met in the bronchioles (a higher air flow means an audible wheeze clinically, which explains the wheeze of bronchiolitis in babies).

Airways conductance is proportional to the radius raised to the fourth power. In normal airways, therefore, the relatively small increase in diameter occurring at about four or five years of age, results in a large change in airway conductance (Hogg, 1970). Conversely, in pathological states, a relatively small encroachment on diameter, will result in greatly increased airways resistance (Comroe, 1962).

The contribution of upper airways to total resistance in infants is substantial. The nasal resistance of infants is nearly half of total respiratory resistance. So, if the infant is a nose-breather normally, then any compromise of nasal airway dimensions will result in labored breathing, as will even mild oedema of the trachea or larynx.

It should be remembered that the area of a circle is πr^2. With growth, the internal diameter of the larynx, trachea and bronchi increases, but the cross-sectional area increases more rapidly, so that narrowing of the airway, due to oedema, exudate, and so on, exerts a relatively greater encroachment on breathing in the younger patient.

Airways obstruction, therefore, tends to be much more severe in infants than in older patients suffering similar degrees of airways disease. The smaller the radius of the airway, the greater the tendency to collapse, hence atelectasis is much more common in the younger age groups specifically, and in children, generally, than in adults.

The Respiratory System

Infants do not have as efficient a respiratory system as adults. They are handicapped by:

A limited reserve,

A narrow trachea, with a large, "floppy" epiglottis,

Relatively soft bronchial and tracheal cartilages,

A poor respiratory mechanism, lacking the later "bucket-handle" action of the ribs, with inhibition of the diaphragm by a large abdomen,

A weaker cough,

Increased nasal resistance,

Lack of mobility,

An immature body heat control—babies do not shiver as adults do.

Pulmonary Hygiene

The pulmonary hygiene of babies and infants can be impaired by the above factors, together with difficulty in clearing secretions owing to:

Lack of mobility—babies lie in the recumbent position for a large part of the time, which puts the upper lobes, particularly, at risk.

Variations in sputum viscosity. Professor Lynne Reid (1971) has suggested that babies up to the age of four or five months have abnormally viscous sputum, because of the sulphate content of the muco-polysaccharides. The sputum of the wheezy, allergic or asthmatic child is often particularly gelatinous and sticky.

Absent or impaired cough reflex, as in cerebral conditions; weakened cough, as in neuro-muscular conditions; ineffective cough, because of either laziness or lowered vital capacity; or the suppressed cough, usually owing to parental or teacher disapproval.

Nasal obstruction, due to anatomical conditions, oedema or simply congestion. Babies cannot clear their nasal passages voluntarily; and older children either cannot, or will not. Air entering the lungs is not then warmed and humidified, nor filtered by the cleansing action of the nasal passage—thus aggravating still further any lower airways obstruction present. If this abnormality persists, mouth-breathing may became a habit.

[1] Delivered at the XIII Biennial Congress of the Australian Physiotherapy Association, Brisbane, August, 1973.

Deformity

Bony deformity of the thoracic cage can result from the continuous, or repeated, use of a faulty breathing pattern and the prolonged use of the accessory muscles of respiration, combined with the over-inflation of the lungs through air-trapping. The chest becomes over-distended, rounded, and moves relatively little with respiration. As the child grows, the posture may become more kyphotic as a result; there may be some asymmetry of the thorax; and the position of inspiration with elevated shoulder girdle, *etc.*, becomes more obvious.

Constitutional Changes

There may be constitutional changes: poor appetite, leading to poor weight gains, resulting in poor percentiles; decreased resistance to secondary infection, especially where retained secretions are present; rapid dehydration in babies suffering moderate to severe respiratory distress—where the increased work of breathing and rapid respiratory rate require copious fluid intake during such episodes; vomiting, often associated with airways obstruction in children, particularly small children, increases the danger of dehydration.

CONDITIONS ENCOUNTERED

Airways obstruction in the paediatric age group may be:

Complete (as in foreign body, mucoid impaction);

Incomplete (as in retained secretions).

The obstruction may be:

In the upper airways (nasal obstruction, tracheal compression, croup),

In the lower airways (sub-segmental, segmental or lobar collapse, *etc.*).

Lower airways obstruction may be:

Within the lumen (for example, mucus plugs, foreign body),

In the wall of the bronchus (for example, mucosal oedema; muscle spasm; tumours),

Peri-bronchial—where the compression of the airway is from without (pressure from tumours; enlarged lymph nodes; vascular ring; and those congenital heart deformities where there are greatly enlarged pulmonary arteries).

The obstruction may be:

Reversible—either medically or surgically—by, for example, bronchodilation and draining of retained secretions, shrinking of mucosal oedema, surgical relief of pulmonary hypertension, or lobectomy,

Irreversible — as in fibrosis or bronchiectasis (where surgical measures cannot be recommended),

Some degree of both—for example, cystic fibrosis, or secondary infection superimposed on an irreversible condition.

PHYSICAL THERAPY

The treatment of airways obstruction in children is most successful where good teamwork is available —both in those patients requiring hospital admission, and those treated as outpatients with parent co-operation.

For effective hospital treatment, physiotherapy should be available for acute cases twenty-four hours a day, seven days a week. Speed and frequency are often vital features of the treatment given. Physiotherapy given to babies and children for relief of airways obstruction will include one or all of the following techniques:

Pulmonary Drainage

Pulmonary drainage presupposes a thorough knowledge of the tracheo-bronchial tree, and to be effective the following factors are essential.

Correct posture of the patient will be determined by the segment of the lobe requiring draining, where localised radiological changes are present, or generalised drainage, where there are no specific localised changes. There may, however, be clinical considerations, such as palpable secretions detected by the physiotherapist, or abnormal features on auscultation, which suggest particular segmental drainage. The angle of drainage, and the posturing of the patient, is the same as for an adult and can be learned from various texts, but Thacker's "Postural Drainage" or "Postural Drainage at Home", by Diana Gaskill, are very explicit. The neo-nate can be drained within the humidicrib where necessary. I think babies and children are best drained on a firm bed or on a table and *not* on the knee, for the following reasons:

The infant is safer and feels more secure.

The operator has both hands free for effective treatment.

The difficulty of progressing to a different method when the child becomes older (particularly in long-term patients, as in cystic fibrosis) is not encountered.

Parents have invariably found it easier, in my experience.

The child should be comfortable and there should be no restrictive clothing, particularly around the neck. Babies and small children are best treated before meals, often three times daily. Older children, treated at home, are best treated on rising in the morning, and last thing before retiring to bed at night.

For generalised drainage, the four lower lobe segmental positions are used mostly (posterior basal; anterior basal; left and right lateral segments). With babies, it is wise to adapt these positions during the treatment by a quarter-turn of the thorax to cover "mid-zone" positions, and treatment of babies should conclude with some drainage of the apical, upper lobe segments.

Drainage of lower lobes precedes upper lobes; and healthy areas should be drained after any infected areas, to clear any "spill" of secretions.

Babies suffering from tracheo-oesophageal fistula, or gastro-oesophageal reflux, may need treatment in the sitting posture, but, if other than upper lobes are involved, it has been my experience that segmental drainage can be safely carried out in the "tipped" position.

Always check with the neuro-surgeon before posturing any child suffering from head injury or brain surgery—percussion, coughing and aspiration can still be given in whichever position may be advised.

Although not universally agreed, it is my view that physiotherapy should never be given for known, or suspected cases of foreign body inhalation (Benjamin, 1973). The danger of moving the foreign body into a major airway, for example, subglottic area of the trachea, may cause total respiratory obstruction. Drainage, of course, may be necessary following bronchoscopy.

Percussion of the chest wall must be vigorous and forceful if it is to be of any value whatsoever. It is a common fallacy that the smaller child will stand nothing but ineffectual "patting". Obviously, one's vigour must be tempered in instances of prematurity, severe illness and general weakness, but for home treatment of the asthmatic-type child, most parents will need to be reassured that they will do the child no harm by vigorous percussion. It should be noted that percussion should not be given below the rib-cage, nor over the sternum (with the spine splinted on a firm base, it can cause the ribs to fracture at the costal angle). The operator's hand should be well cupped, so that the enclosed air "cushions" the transmitted force. The resultant rib-spring, in babies, will generally provoke a cough, though not so commonly in the older child: in either case a cough may need to be elicited by other means. Percussion should continue for only 20 to 30-second intervals before a cough is attempted.

Vibration of the chest wall, following percussion, is most successful in moving secretions, I find, when carried out in conjunction with the patient's own voluntary effort of forceful expiration simultaneous with the vibrations. This squeezing effect on the airway seems to shift the retained secretions to a higher level and is quite often audible. However, I have not found vibrations to be of much help in babies and small children unable to co-operate in the technique.

Deep breathing, where the child is old enough to co-operate, is helpful in gaining a maximum efficiency of cough. Apart from helping to gain the effect referred to above, a deep inspiration should always precede a cough, so that sufficient air is taken in under the obstruction for adequate clearing. This increased ventilation will also help in re-expanding any areas of collapse. In babies, and small children, therefore, the crying which often accompanies our procedures is only beneficial.

Coughing is obviously the most important part of the treatment. Gravity, alone, is certainly not sufficient to drain excess secretions and it is a grave error to simply posture a patient and leave gravity to do the work. In many cases, no amount of percussion or vibration will shift secretions either, and it is absolutely essential to provoke a cough in any patient, at any age, if we are to be successful in draining secretions and relieving obstruction.

The cough may be provoked, by any of the above methods; *voluntary*, if a patient can be trained to cough properly on request, *spontaneous*, caused by secretions shifting, body movement, altered position, *etc.*, or *stimulated*, especially in babies and infants. It is important to realise that a cough is a protective reflex, which is stimulated generally in the lower airways of the bronchial tree; but it can be stimulated in the upper airways. It is therefore important to stimulate the cough repeatedly in small children, and those unable to cough, for any reason, at pharyngeal level. It is easily done by using a fine rubber catheter (the distance from the ear to the mouth is approximately the same distance as from the mouth to the pharynx). This reflex, like any other, can become conditioned, and babies from about eight months of age will learn to cough on seeing the catheter moved towards the mouth. This stimulation is particularly important in the treatment of cystic fibrosis, where daily drainage is mandatory.

Suppression of coughing may sound like a contradiction of terms, but many children have learned to stop themselves coughing, and, if they are stimulated to cough at all, will promptly stifle it. These children need intensive cough re-education, particularly where they have been punished for coughing (most parents cannot tolerate a disturbing nocturnal cough). Some children, also, have been given cough suppressants—a practice not to be recommended.

Nasal clearing. Children should be taught to blow their noses as soon as possible and during drainage, the nasal passages should be cleared at regular intervals. Babies, especially, tend to drain through the nose with treatment. Where babies and small infants are being drained, naso-pharyngeal suction, as well as oro-pharyngeal, should be employed. It is not uncommon for the nose to bleed—either caused by oedematous, hyperaemic nasal mucosa or to adenoidal bleeding—but usually this can be ignored. However, suction should not be used following surgical removal of adenoids or tonsils or following cleft palate repair.

The foregoing points are the essentials of adequate draining, which should be repeated in sequence up to a total drainage time of twenty minutes where necessary, although babies tend to clear much quicker and also, their treatment time should not be extended too long because it may cause undue fatigue interfering with their ability to suck and feed.

Special mention should be made of the drainage of cystic fibrosis patients, who should be drained routinely at least twice daily from the moment of diagnosis. The complete physical treatment of these children has been discussed by the author in detail previously (Morony, 1969, 1970), but it is absolutely essential that every segment of every lobe be drained daily, prophylactically, and more often and more vigorously at times of acute infection.

Sputum should be sent for bacteriological examination wherever secondary infection is suspected, and regularly at 4-6 weekly intervals in patients with cystic fibrosis. The sputum should be that resulting from a good cough, and may be trapped in a special "sputum-trap" in the case of children too young to expectorate. The physiotherapist is, in my opinion, the person most suitable to collect this specimen, or to suggest when its appearance indicates bacteriological examination for culture and sensitivity.

OXYGEN THERAPY

Babies and children suffering from acute airways obstruction and moderate to severe respiratory dis-

tress, may require oxygen. The baby may be nursed in a humidicrib, "biscuit tin", croupette or other form of oxygen tent. It is most important never to remove the child from the tent for treatment without having some stand-by oxygen available, even when the child is able to withstand periods of time away from the oxygen. Even where the child is not being nursed continuously in oxygen, it is often helpful to give three or four puffs of oxygen *via* a face mask before stimulating a cough, or, following a cough, to relieve any resultant distress or cyanosis, particularly in cardiac patients with secondary airways obstruction, children with advanced cystic fibrosis, or children with paroxysmal cough of any type. An Intermittent Positive Pressure Respirator may be more effectively used, in some cases, if driven from an oxygen source, particularly if incorporating an aerosol for the relief of bronchospasm.

Inhalation Therapy

An Intermittent Positive Pressure Respirator (such as the Bird or Bennett) is used in the treatment of airways obstruction in the following manner:

For effective bronchodilator therapy in asthmatic conditions (for example, wheezy bronchitis, allergic bronchitis) where certain medications are nebulized for delivery directly into the tracheo-bronchial tree—often *via* a source of oxygen, as previously mentioned.

At the Royal Alexandra Hospital for Children, Sydney, the usual practice is to give the child 10 puffs of 2% orciprenaline ("Alupent") at 15 cm H_2O pressure, *via* a face mask. Where infants are too young to co-operate in cycling the machine, the baby's head should be firmly supported from behind while the mask is applied very firmly—allowing no air leak. The infant will probably cry—thus triggering the machine effectively. If the child's vital capacity is too low to trigger the cycling (particularly the expiratory phase in acute asthma, for instance) some assistance manually may be required from the operator, even when the sensitivity has been adjusted.

For inhalation of mucolytic agents, where the retained secretions are thought to be thick or particularly tenacious, such as in chronic bronchitis or cystic fibrosis, nitrogen acetyl-cysteine may be used combined with a bronchodilator if recommended.

For improved ventilation, particularly for re-expansion of sub-segmental, segmental or lobar collapse, normal saline, sterile water, propylene-glycol, or any other suitable medication can be used (generally a 2 ml inhalation is given at an appropriate pressure, from an air source).

Intermittent Positive Pressure Respiration is contra-indicated in cystic fibrosis except in rare, selected instances (National Cystic Fibrosis Research Foundation). Such use should, in my opinion, be only on the recommendation of a paediatrician well-experienced in cystic fibrosis treatment.

Metered aerosols may also be used for bronchodilation—especially in the home—prior to drainage, where the cough sounds "constricted" or "choked", or where drainage techniques cause increased wheeze or distress. The most commonly used are orciprenaline (Alupent) and salbutamol (Ventolin). My method, and that recommended for home use, is to give the child two puffs—one minute apart—immediately prior to drainage, or, at other times, when indicated for the relief of bronchospasm, asthma attacks, *etc.*, at four-hourly intervals. The parents, and patient, must be precisely instructed in complete details of this therapy—both in administration and in safety of use, so that it is used correctly. A complete expiration should be given before the inspiration (inhalation) and the child's lips should completely seal the mouthpiece. The child should be taught how to hold the breath for maximum inhalation before removing the puffer from the mouth. Where the child is very small, the parent will require considerable training in synchronising the aerosol release with the child's inspiration; a device containing only inert propellant is useful for practice.

Intermittent inhalation, or nebulisation therapy, is sometimes used in conditions such as chronic bronchitis (always in cystic fibrosis) for the administration of medications *via* a nebuliser driven by a source of compressed air (for example, the Maximyst, Repco or Dynavac Pumps). A mouthpiece rather than a mask is thought to be more beneficial in depositing the particles further down the tracheo-bronchial tree. Propylene-glycol or Mucomyst, for example, with or without a bronchodilator, are commonly used—2 ml being the usual dosage. Antibiotic inhalation, such as neomycin sulphate, or gentamicin, are given in cystic fibrosis, and are best given following drainage. The child should be supervised, so that deep inspiration is constant, and the mist does not simply pervade the atmosphere.

Sodium chromoglycate ("Intal") is now used extensively in paediatrics and is probably more successful in controlling asthmatic conditions in childhood than in adults. If the indications are present, "Intal" can be given at any age, even in the neonatal period. Most children over the age of three can learn to use the "Spinhaler". If this cannot be mastered, the Intal may be given by three alternative methods:

1. Nebuliser with hand pump (for example, No. 42 DeVilbiss nebuliser). The capsule is opened, and the powder placed into the mouthpiece and dissolved in a very small quantity of sterile water (approximately 0·6 ml will suffice). This is placed into the baby's mouth (a Morris feeding-bottle top, or cut-off dummy, attached over the mouthpiece will protect the palate) and the rubber pump compressed to time with inspiration until all the liquid has been delivered.
2. A "Rynacrom" Insufflator can be used, puffing the contents of an Intal capsule into the baby's mouth (not nose) as before. The white end must be inserted first, and patience will be required in replacing the screw top nozzle of the Insufflator. (Rynacrom capsules can be used. Two Rynacrom capsules equal one Intal capsule in powder content.)
3. An air-compressor can be used to nebulise the mixture made from one Intal capsule dissolved in 2 ml of sterile water. This method involves the expense of purchasing the air-compressor, however. Patients should be given Intal after drainage, where this is being given.

Nocturnal mist-tent therapy for cystic fibrosis patients, preferably delivered by an Ultra Sonic Nebuliser for appropriate particle size (0-5 microns) (Mathews and Doershuk, 1968).

Resuscitation

All physiotherapists treating thoracic conditions, whether in hospital or in private rooms, should have oxygen and suction equipment ready for use and should know how to give emergency resuscitation. There is always a possibility of dislodging an unsuspected foreign body, or a large plug of mucus, into a major airway, causing temporary and/or complete respiratory obstruction and arrest. The smaller the child, the more real the danger.

Ventilatory Function Testing

Objective testing of pulmonary function is necessary for satisfactory diagnosis, assessment of treatment, and progress of a child old enough to co-operate (usually 5 or 6 years). The most readily accessible method is by the use of the Vitalograph. Children can usually expire more than 90% of their total Vital Capacity in the first second, in normal health (Kendig, 1967). Any reduction in the FEV_1/FVC may be due to poor co-operation, muscle weakness, or lower airways obstruction. When improved by the inhalation of bronchodilator, some asthmatic-type condition may be diagnosed. The FVC should also be expressed as a percentage of the predicted (for height) FVC, both before and after bronchodilator.

Breathing Techniques

It is now generally recognised that a child will breathe "as best it can" given certain abnormal physiological states. A baby and small child will rely heavily on the use of the accessory muscles of respiration, particularly the abdominals, in respiratory distress. There has been much talk of "getting the patient to relax" to correct the breathing pattern in an asthmatic attack; but infants simply cannot understand this procedure. One has only to witness a baby's distress to realise that, should these asthma attacks continue throughout its earliest years, fear and anxiety will constitute an increasing component of future attacks. One has to train the parents to relax—if possible—and this must be a real challenge for a parent. Certainly, they should try hard not to transmit their anxiety and fear to the child, however young, as children are quick to gauge, from the parents' facial expressions, their inner feelings. Children hyper-secrete very quickly in an asthma attack, and parents should be taught how to deal with the condition. Manual compression of the thoracic cage during an attack seems to help often, and older children can be taught a correct breathing pattern to practise when well—hopefully they may be able to abort some episodes by self-help when necessary.

Any exercise involving breathing combined with arm exercise should be avoided, as this tends to confuse the child and/or aggravate the "shallow" breathing already present. General, or specialised, activity to improve the exercise tolerance should be encouraged.

Posture Correction

Posture correction may be attempted where postural deformity is developing. However, if the airways obstruction is of a recurrent nature, it is far more beneficial for the patient and parent to concentrate on clearing secretions and to maintain maximum airway efficiency and ventilation, thus trying to prevent this later complication.

Motivation and Co-operation

In treating recurrent airways obstruction in children, one is, in the most part, dependent on a third party—that is, the parent—for success. Education and instruction will help to motivate the parents, and thus obtain their co-operation in carrying out the home therapy, where necessary.

As the child becomes older, we must obtain, then retain, the child's interest. I find that young children are quite interested in diagrams of the lungs and their function, and will spend lengthy periods "treating" their own dolls and teddy-bears —thus ensuring their own co-operation with treatment.

SUMMARY

The anatomical and physiological background related to airways obstruction in childhood and its relation to methods of physiotherapy techniques is outlined.

Conditions most often encountered and their treatment by the use of physiotherapy measures, including postural drainage of the lungs, oxygen therapy and inhalation therapy, are also discussed.

REFERENCES

BENJAMIN, B., 1973. *Medical Journal of Australia* (in print) and by personal communication.

COMROE, J. H., 1962. *The Lung.* Year Book Medical Publishers.

DUNNILL, M. S., 1962. Postnatal Growth of the Lung. *Thorax*, 17: 329-333.

GASKILL, D., 1967. *Postural Drainage at Home.* The Brompton Hospital, London.

HOGG, J. C., 1970. Age as a Factor in the Distribution of Lower-Airway Conductance. *The New England Journal of Medicine*, 282; 23.

KENDIG, R., 1967. *Disorders of the Respiratory Tract in Children.* W. B. Saunders, Philadelphia.

MATHEWS, L., and DOERSHUK, C., 1968. *Evaluation of Jet-type and Ultrasonic Nebulizers in Mist Tent Therapy for Cystic Fibrosis.* First Conference on Clinical Application of Ultrasonic Nebulizer, Western Reserve University, Cleveland.

MORONY, T., 1969. Cystic Fibrosis. *Australian Journal of Physiotherapy.* 4; XV.

MORONY, T., 1970. Cystic Fibrosis. *Physical Therapy.* 1; 3.

NATIONAL CYSTIC FIBROSIS RESEARCH FOUNDATION, New York. *Guide to Diagnosis and Management of Cystic Fibrosis.*

REID, L., 1971. Personal Communication.

THACKER, W., 1965. *Postural Drainage and Respiratory Control.* Lloyd-Luke, London.

ACKNOWLEDGEMENTS

I am especially indebted to Drs. John Alexander, John Brown and John Overton, of the Royal Alexandra Hospital for Children, Sydney, for reading this paper, and for their helpful suggestions.